

## Principle GNSS-R Scattering Modes and Their Detection on a Global Scale Using CYGNSS Level-1 Delay Doppler Maps

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Spaceborne measurements of bistatic land surface specular scattering from Global Navigation Satellite System-Reflectometry (GNSS-R) systems are producing increasing interest in applications that include soil moisture retrieval, vegetation biomass retrieval, river flowrate gauging, and wetland dynamics observation.

CYGNSS, launched December 2016, is a first of its kind NASA Earth Venture Mission that operates a constellation of eight satellites receiving GPS signals reflected from Earth's surface. While the primary scientific mission of CYGNSS is to measure scattering from the ocean's surface and to utilize these measurements for ocean wind speed retrieval, studies analyzing its land returns clearly demonstrate sensitivity to land surface properties for points within its +/-38° latitude coverage. CYGNSS's land surface measurements show extreme variability due to the presence of both incoherent and coherent scattering effects. Due to the desire to develop remote sensing algorithms that are resilient to this variability, it is crucial to be able to identify and separate these returns as an initial step prior to the use of CYGNSS's land measurements.

Previous studies have typically attempted to develop and apply coherence detection schemes in the context of GNSS-R sea-ice detection, relying on mean values of the Delay Doppler Map Average (DDMA) within varying delay-Doppler extents, Signal-to-Noise Ratios (SNR), DDM Trailing Edge Slopes, matched filter correlations, or a combination of these approaches each with varying levels of success. Due to the desire to develop a robust method that enables detection of coherent returns for all CYGNSS measurements, an alternative methodology is explored in this work that is based on the well-established expected response of DDMs under dominantly coherent and dominantly incoherent scattering regimes.

Due to the fact that dominantly incoherent DDMs are the result of scattering from a statistically rough surface, an appreciable mapping of power at increasing delays from the specular bin occurs. This together with the intersection of constant delay ellipses and constant Doppler hyperbolas gives rise to the characteristic "horseshoe" shape of the incoherent DDM. In contrast, coherent returns arise due to reflection off a smooth surface from a region whose size is on the order of a Fresnel zone, resulting in a concentration of power around the specular bin characterized by a sharp peak, and a rapid decay in power at bins exceeding +/-0.25 chips in delay and +/-1 kHz in Doppler. The proposed approach therefore leverages the increase in power spread across the varying types of DDMs through a coherence metric, the power ratio (PR), to classify CYGNSS Level-1 DDMs as dominantly coherent or dominantly non-coherent. Because the focus of the proposed methodology is to determine the coherency state based on the relative concentration of power within differing regions of DDMs, it is concerned with DDM "shape" as opposed to amplitude and therefore bypasses uncertainties associated with absolute power calibration by applying the detection methodology to DDMs in uncalibrated raw counts.

In addition to providing an overview of the basic formulation of the proposed Level-1 coherence detector, this presentation will provide an analysis of its detection capability relative to "gold standard" coherence detection results that relate to the phase of the received surface scatter using CYGNSS Raw I/F downlinks at local-to-regional scales. The presentation will also discuss the prevalence of coherence over both land and sea surfaces observed in CYGNSS data, and the information this provides on properties of these surfaces.